Evaluating the Use of Cone-Beam Computed Tomography (CBCT) in Diagnosing Impacted Teeth: A Comparative Analysis with Conventional Radiography

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Abstract

Impacted teeth, particularly third molars and canines, pose significant challenges in dental practice due to their unpredictable positions and potential complications. Accurate diagnosis is crucial for effective treatment planning. This study compared the efficacy of Cone-Beam Computed Tomography (CBCT) and conventional panoramic radiography in diagnosing impacted teeth, focusing on diagnostic accuracy, treatment planning, and clinical outcomes. A retrospective cohort analysis was conducted on 150 patients in a tertiary hospital setting. The findings indicated that CBCT provided superior diagnostic accuracy, including higher sensitivity, specificity, and positive predictive value, compared to panoramic radiography. CBCT was also more effective in detecting anatomical relationships and complications, such as root resorption, making it a valuable tool for reducing surgical risks. However, concerns about increased radiation exposure and costs were noted. The study supports integrating CBCT into diagnostic workflows for complex cases involving impacted teeth, while balancing the benefits with associated risks.

Keywords: Cone-Beam Computed Tomography, Impacted Teeth, Panoramic Radiography, Diagnostic Accuracy, Dental Imaging, Treatment Planning

Introduction

Impacted teeth, particularly third molars and canines, present a significant challenge in dental practice due to their unpredictable positions and potential complications if left untreated. Accurate diagnosis of impacted teeth is crucial for planning surgical interventions, minimizing associated complications, and ensuring optimal treatment outcomes (Bishara, 1992). Traditionally, conventional radiographs, such as panoramic radiography, have been the mainstay in diagnosing impacted teeth. However, these two-dimensional (2D) techniques are often limited in their ability to provide precise information on the spatial positioning of teeth and their relation to adjacent anatomical structures (Scarfe & Farman, 2008).

With advancements in imaging technology, Cone-Beam Computed Tomography (CBCT) has emerged as a superior diagnostic tool for evaluating impacted teeth. Unlike conventional radiographs, CBCT provides three-dimensional (3D) imaging, allowing for a more detailed assessment of the impacted tooth's position, orientation, and its proximity to critical structures such as the mandibular canal and maxillary sinus (Kapila

et al., 2011). This enhanced imaging capability is particularly beneficial in complex cases, as it allows for better visualization of the spatial relationships that are crucial for effective treatment planning.

The increased use of CBCT in dentistry, especially in orthodontics and oral surgery, has led to improved decision-making and risk assessment for impacted tooth extraction. Studies have shown that CBCT provides greater diagnostic accuracy and reduces the risk of complications during surgical interventions by offering high-resolution, 3D images (Walker et al., 2015). Despite the benefits, concerns remain regarding the increased radiation dose associated with CBCT compared to conventional imaging, necessitating a careful consideration of its use on a case-by-case basis (Ludlow et al., 2008).

This study aims to compare the efficacy of CBCT with conventional radiography in diagnosing impacted teeth, focusing on diagnostic accuracy, treatment planning, and overall clinical outcomes. By highlighting the advantages and limitations of each modality, we seek to provide insights that will aid dental professionals in selecting the most appropriate imaging technique for managing impacted teeth.

Literature Review

Impacted teeth are a common issue encountered in dental practice, particularly in cases involving third molars and maxillary canines. Proper diagnosis and management of these impacted teeth are essential to avoid complications such as resorption of adjacent teeth, infection, or cyst formation (Bishara, 1992). Traditional methods of imaging, such as panoramic radiography and intraoral periapical radiographs, have been extensively used for diagnosing impacted teeth. However, these 2D imaging methods come with inherent limitations, including distortion, magnification, and a lack of depth information, which can affect the accuracy of diagnosis (Scarfe & Farman, 2008).

In recent years, Cone-Beam Computed Tomography (CBCT) has gained prominence in the field of dentistry, especially for assessing complex dental and maxillofacial conditions. CBCT technology provides high-resolution, 3D images, allowing for a more comprehensive evaluation of the impacted tooth's location and its spatial relationship to adjacent anatomical structures, such as nerves and sinuses (Kapila et al., 2011). Studies comparing CBCT to conventional radiographs have consistently shown that CBCT provides superior diagnostic accuracy, particularly in cases where the impacted tooth is in close proximity to critical anatomical structures (Walker et al., 2015). This advantage is critical in reducing the risk of complications during surgical procedures, such as nerve damage or sinus perforation.

Walker et al. (2015) conducted a study that highlighted the effectiveness of CBCT in the three-dimensional localization of impacted maxillary canines, emphasizing its value in treatment planning. Their findings indicated that CBCT provides significantly greater accuracy in determining the precise position of impacted teeth compared to panoramic radiographs. Similarly, Kapila et al. (2011) underscored the importance of CBCT in orthodontic treatment planning, particularly in cases involving impacted canines, where detailed visualization is necessary for effective decision-making.

Despite its advantages, the use of CBCT is not without limitations. One of the primary concerns associated with CBCT is the increased radiation dose compared to conventional imaging techniques. Ludlow et al. (2008) investigated patient radiation exposure from CBCT and concluded that while the radiation dose is higher than that of traditional radiographs, it is still within acceptable limits for clinical use when justified by the diagnostic benefits. The decision to use CBCT should therefore be made based on a careful

consideration of the potential benefits and risks, particularly in younger patients who are more sensitive to radiation.

Another consideration in the use of CBCT is cost. The equipment required for CBCT is more expensive than that for conventional radiography, which may limit its availability in some dental practices, particularly those in resource-limited settings. Additionally, the interpretation of CBCT images requires specialized training to ensure accurate diagnosis and avoid misinterpretation of anatomical structures, which can lead to unnecessary interventions or missed diagnoses (Scarfe & Farman, 2008).

Nonetheless, the consensus in the literature is that CBCT offers significant advantages over traditional imaging methods, particularly in complex cases where precise localization of impacted teeth is critical. The 3D imaging capabilities of CBCT provide a more accurate assessment of the impacted tooth's relationship with surrounding structures, which can improve treatment outcomes and reduce the risk of surgical complications (Kapila et al., 2011; Walker et al., 2015).

In summary, the literature suggests that while conventional radiographs remain useful for initial assessments, CBCT provides superior diagnostic accuracy and detailed visualization that is essential for the effective management of impacted teeth. However, considerations regarding radiation exposure, cost, and the need for specialized training must be taken into account when deciding on the appropriate imaging modality for each patient.

Methodology

This study was conducted in a tertiary hospital with a well-established dental and maxillofacial surgery department. The research aimed to compare the efficacy of Cone-Beam Computed Tomography (CBCT) with conventional panoramic radiography in diagnosing impacted teeth. The study design was a retrospective cohort analysis involving patients who had undergone imaging for impacted teeth over the past two years.

Participants

The study included a total of 150 patients who were referred to the dental and maxillofacial department for the evaluation of impacted teeth. The inclusion criteria were patients aged 18 years and above who had undergone both CBCT and conventional panoramic radiography as part of their diagnostic workup. Patients with incomplete imaging records or those with contraindications for CBCT were excluded from the study.

Data Collection

Data were collected from the hospital's electronic medical records system. For each patient, both CBCT and panoramic radiography images were retrieved and reviewed. The imaging data included the position, orientation, and proximity of the impacted tooth to critical anatomical structures, such as the mandibular canal or maxillary sinus. Two experienced oral radiologists independently evaluated the images, and any discrepancies were resolved through consensus.

Imaging Evaluation

The evaluation focused on several key diagnostic parameters, including the accuracy of tooth localization, identification of anatomical relationships, and detection of potential complications such as root resorption of adjacent teeth. Each parameter was scored on a standardized evaluation form, and the diagnostic accuracy of CBCT and panoramic radiography was compared using these scores.

Statistical Analysis

Descriptive statistics were used to summarize the demographic characteristics of the study population. The diagnostic accuracy of CBCT and panoramic radiography was compared using sensitivity, specificity, and positive predictive value. The data were analyzed using SPSS software, and statistical significance was set at $p < 0.05$. Inter-observer reliability was assessed using Cohen's kappa coefficient to determine the consistency between the two radiologists' evaluations.

Ethical Considerations

The study was approved by the ethics committee, and all data were anonymized to ensure patient confidentiality. Given the retrospective nature of the study, informed consent was waived by the IRB, as no direct patient contact was involved.

Findings

The study included 150 patients, of which 85 were female and 65 were male. The average age of participants was 29.7 years (range 18-55 years). The findings are summarized in the tables below.

Table 1: Demographic Characteristics of Participants

Characteristic	Number of Patients (n=150)
Gender	
- Female	85
- Male	65
Average Age (years)	29.7
Age Range (years)	18-55

Table 2: Diagnostic Accuracy of CBCT vs. Panoramic Radiography

Imaging Modality	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)
CBCT	95	92	94
Panoramic Radiography	78	85	80

Table 3: Detection of Anatomical Relationships and Complications

Parameter	CBCT (n=150)	Panoramic Radiography (n=150)
Accurate Tooth Localization	145 (97%)	117 (78%)
Identification of Mandibular Canal	140 (93%)	105 (70%)
Detection of Root Resorption	130 (87%)	95 (63%)

Inter-Observer Reliability

The inter-observer reliability for CBCT evaluations was excellent, with a Cohen's kappa coefficient of 0.85, indicating strong agreement between the two radiologists. For panoramic radiography, the kappa coefficient was 0.72, indicating moderate agreement.

Discussion

The findings of this study demonstrate the significant advantages of using CBCT over conventional panoramic radiography for diagnosing impacted teeth. CBCT's superior diagnostic accuracy, as evidenced by higher sensitivity, specificity, and positive predictive value, highlights its effectiveness in providing precise localization and a clearer understanding of the spatial relationships between impacted teeth and adjacent anatomical structures. This capability is particularly important in treatment planning, where accurate information is crucial to avoid complications during surgical interventions.

The data presented in this study align with the findings from previous literature, such as those reported by Walker et al. (2015) and Kapila et al. (2011), which emphasized the enhanced diagnostic capabilities of CBCT in the assessment of impacted maxillary canines and other complex dental conditions. The higher accuracy of CBCT in identifying key anatomical landmarks, such as the mandibular canal, and in detecting complications like root resorption, underscores its value in both diagnostic and therapeutic contexts. The three-dimensional imaging provided by CBCT ensures that clinicians have comprehensive information, thereby facilitating more effective and predictable surgical interventions.

One of the key implications of these findings is the potential for CBCT to reduce the risk of surgical complications, such as nerve damage or sinus perforation. In particular, the accurate identification of the mandibular canal, achieved in 93% of cases with CBCT compared to 70% with panoramic radiography, suggests that CBCT could play a crucial role in minimizing surgical risks. This is particularly relevant for procedures involving impacted mandibular third molars, where the proximity of the tooth to the mandibular nerve increases the risk of iatrogenic injury.

Despite these advantages, there are still concerns regarding the increased radiation exposure associated with CBCT. While Ludlow et al. (2008) reported that the radiation dose from CBCT is higher than that of conventional radiography, it is still within acceptable limits for clinical use when the diagnostic benefits justify its application. The decision to use CBCT should therefore be individualized, taking into account factors such as patient age, clinical necessity, and the potential risks associated with radiation exposure. It is particularly important to weigh these factors in younger patients, who may be more susceptible to radiation-induced effects.

Another limitation of CBCT, as highlighted in this study, is its cost and the need for specialized equipment and training. The higher cost of CBCT equipment, compared to conventional radiography, may limit its widespread adoption, particularly in resource-limited settings. Additionally, accurate interpretation of CBCT images requires specialized training, and misinterpretation can lead to incorrect diagnoses or inappropriate treatment plans. Therefore, continued education and training for dental professionals in the use of CBCT are essential to maximize its diagnostic potential while minimizing risks.

The moderate inter-observer reliability observed with panoramic radiography, compared to the excellent reliability with CBCT, further supports the use of CBCT as a more consistent diagnostic tool. The higher kappa value for CBCT indicates that it provides clearer and more interpretable images, reducing variability between clinicians and enhancing diagnostic confidence. This consistency is particularly valuable in multidisciplinary settings where multiple professionals may be involved in patient care.

Overall, the findings of this study support the integration of CBCT into routine diagnostic workflows for cases involving impacted teeth, particularly when precise anatomical localization and risk assessment are

critical for treatment success. However, it is essential to adopt a balanced approach, considering the potential benefits and limitations, including radiation exposure and cost. Future studies could focus on further optimizing CBCT protocols to reduce radiation doses while maintaining diagnostic quality, as well as exploring its cost-effectiveness in different clinical settings.

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